

## RIPARIAN ECOSYSTEMS AND BUFFERS – MULTISCALE STRUCTURE, FUNCTION, AND MANAGEMENT: INTRODUCTION<sup>1</sup>

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Riparian ecosystems provide critical ecological functions that serve to mitigate the impacts of land use activities, such as forest harvest and agriculture, on aquatic ecosystems and water resources. Because riparian zones occur where many biotic and physical processes change and materials are transformed, they serve as mediators and integrators of the land-water interface, and there is considerable concern regarding their protection, restoration, and management (Gregory *et al.*, 1991; Naiman and Decamps, 1997). The values and functions associated with streams and riparian areas generally are protected through the establishment of buffer strips or the legal designation of riparian management zones. However, current understanding of the processes underlying certain riparian functions and the effectiveness of management practices in maintaining desired functions is still somewhat limited. Despite several decades of focused research, riparian areas continue to be frontiers for the study of land/water interactions, ecosystem processes, restoration techniques, and impacts of watershed and landscape management (NRC, 2002; Naiman *et al.*, 2005).

Given the importance of issues related to improved understanding and management of riparian ecosystems and buffers, the American Water Resources Association (AWRA) sponsored a Summer Specialty Conference in June 2004 at Olympic Valley, California, entitled “Riparian Ecosystems and Buffers: Multiscale Structure, Function, and Management.” The primary objective of the conference was to provide a forum for the presentation, exchange, and discussion of current research on national and international

riparian topics and an overview of the latest science and management of riparian areas and buffers. This special issue of the *Journal of the American Water Resources Association (JAWRA)* contains 17 papers on a number of riparian issues presented at the 2004 conference, reflecting the diverse range of topics discussed.

Three papers in this special issue focus on the critical role of riparian zones and other buffers in the maintenance and improvement of water quality in agricultural areas. Inamdar critiques the limitations of current approaches for modeling nutrient transformations that occur in riparian buffers located in areas of intense agricultural use. The author summarizes the disparity between recent improvements in the understanding of water and solute movement in watersheds and ongoing modeling efforts, and addresses the challenges encountered in the application of modeling results to the design of riparian buffers. Dabney, Moore, and Locke review the different types of riparian buffers and their relative roles and uses in agricultural landscapes. The authors discuss the benefits provided by in-field, edge-of-field, and after-field buffers, and how each buffer type functions to improve both surface and subsurface water quality. Shields, Langendoen, and Doyle review existing models, such as those used in the Conservation Effects Assessment Project, that evaluate the effectiveness of federal conservation programs in agricultural watersheds. A primary goal of these programs is to improve stream quality, yet the major criteria for measuring stream response to restoration activities or land use changes are water quality and quantity. The

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authors critique the limitations of current models and propose incorporation of additional variables to better assess stream habitat, suggesting that stream ecological and habitat quality indices would contribute to assessments of conservation programs.

Two papers describe the role of wetlands and riparian buffers in protecting the water quality of Lake Tahoe (California and Nevada), a large, scenic, high elevation lake that is valued for its clarity and located in a basin that is experiencing rapid urbanization and development. Cobourn summarizes the policy and implementation activities for protection of riparian areas surrounding the Lake Tahoe Basin from development and disturbance, an extensive effort regulated by the Tahoe Regional Planning Agency to protect the lake from sediment and nutrient inputs. In a complementary paper, Heyvaert, Reuter, and Goldman document the effectiveness of a constructed wetland system designed to treat stormwater runoff before it enters Lake Tahoe. The wetland and riparian protection in the Tahoe basin is unique in that it is supported by multiple levels of government, applies to public and private lands, and is particularly stringent and strongly enforced.

The last paper focusing directly on improvement of water quality through riparian management presents a case study located in rural southeast Wyoming. Ellison, Skinner, and Reddy studied the relationship between stream discharge and suspended sediment concentrations in Sage Creek, a tributary and source of sediment to the North Platte River. Portions of Sage Creek were being restored and grazing best management practices were underway to reduce sediment inputs, with limited success. Their results indicate that the effectiveness of certain restoration and management efforts in improving water quality is limited by local geology and natural physical processes. Whereas issues vary with land use and location, the common theme of these six papers is the importance of managing riparian zones to maximize their ability to filter, transform, or retain pollutants, as well as maintain stream habitat quality.

Three papers highlight the importance of riparian vegetation for stabilization of streambanks and consequent maintenance and improvement of water quality. Although the role of riparian vegetation in mitigating streambank erosion has been acknowledged for some time, data and modeling results have been scarce. Wynn and Mostaghimi evaluated the relative effects of woody and herbaceous riparian buffers on streambank erosion by measuring the erodibility and critical shear stress of streambank soils in southwestern Virginia. They provide a quantitative analysis of the effects of vegetation on streambank erosion, relative to soil physical and chemical parameters.

Zaimes, Schultz, and Isenhardt present results on streambank erosion along stream segments in central Iowa bordered by riparian forest buffers, row crop agriculture, and grazed riparian pastures. They report that streambank erosion and total soil loss were significantly lower along stream segments vegetated with riparian forest buffers, and recommend establishment of additional forest buffers to reduce soil loss from streambanks. Simon, Pollen, and Langendoen combined field data and modeling results to illustrate the influence of two woody plant species on streambank stability along the Upper Truckee River, California. They integrated data on soil and streambank physical properties with information on plant rooting systems to address the feedbacks between riparian plant roots and bank stability. Collectively, these three papers contribute to improved understanding of the interactions between physical processes and riparian plant attributes that increase streambank stability and reduce inputs of fine sediment to streams.

Economic considerations for management and restoration of wetland and riparian areas are addressed in two papers. Ice, Skaugset, and Simmons discuss tradeoffs between regulations for riparian management during forest harvest, particularly near headwater streams, and the economic costs of alternatives. They review the effectiveness of best management practices in riparian management zones and provide a case study application of geographic information system (GIS) tools for evaluating costs of protected riparian areas. The authors also raise practical questions about the price of maintaining riparian buffers in forested watersheds. Prato presents an economic analysis of wetland and riparian restoration activities along the Illinois River, an important tributary in the upper Mississippi River Basin. Using economic tools to assess costs and benefits, the author concluded that restoration efforts have positive net economic impacts on the regional economy. Using different approaches, the authors of these two papers integrate socioeconomic concerns into the evaluation of riparian and wetland management.

Three papers focus on the assessment of riparian and wetland condition, an important management topic. Goetz reviews the current status and recent advances of remote sensing applications for assessment and characterization of riparian buffers. The author describes the potential for remote sensing tools and approaches, such as light detection and ranging systems (LIDAR), to monitor changes following restoration activities and to evaluate prevailing management actions, thus aiding in buffer zone design and protection. Herring, Schultz, and Isenhardt summarize a GIS inventory of riparian buffers for

three watersheds in northeast Missouri, and discuss results relative to regional National Resource Conservation Service recommendations. Using existing land use data, riparian buffers were characterized according to their length, width, vegetative composition, surrounding land use, and relative areal extent within their respective catchment area. Sutula, Stein, Collins, and Fetscher present an overview of the California Rapid Assessment Method (CRAM), a largely qualitative assessment technique, and discuss the benefits and limitations of this method relative to other rapid assessment methods for evaluation of wetland and riparian resources. The authors provide a context of background information on rapid assessment methods, describe the multiple steps involved in the development of CRAM, and present a California case study of the key issues associated with development and implementation of rapid assessment techniques. Rapid assessment methods and remote sensing and GIS tools show promise in meeting monitoring needs because they can provide cost effective estimates of wetland and riparian condition.

Additional aspects of riparian ecology, restoration, and management are presented in three papers. The provision of large wood to streams, an important riparian function in forested landscapes, is discussed in Liquori's paper. The author focuses on rates of treefall, primarily associated with wind, treefall pattern (random versus directional), and short term mortality rates in riparian buffers following forest harvest in central Washington. Liquori discusses the implications of his results to wood recruitment processes in riparian buffers and offers ideas for improving buffer management in managed forests. The author's results contribute to the understanding of post-harvest dynamics in riparian buffers, and will be useful in further development of treefall regimes and in refining existing woody debris models. Pezeshki and Shields present results from three riparian restoration projects in Mississippi involving the environmental factors that influence the survival of black willow cuttings. The authors found that soil texture and moisture are critical to plant success at their streamside restoration sites. Dwire, Ryan, Shirley, Lytjen, Otting, and Dixon present results on the short term growth of riparian vegetation following wildland fire in western Wyoming. The authors found that herbivory by native ungulates and livestock influenced the growth of several key shrub species, thereby potentially slowing the rate of post-fire recovery along stream riparian corridors. Taken together, these three papers emphasize the importance of understanding and incorporating basic ecological processes when defining management and restoration options for riparian areas.

The papers published here and presented at the conference in June 2004 illustrate the diversity of research and management approaches to riparian zones and buffers. A recurring theme, however, is the concern regarding the effectiveness and impacts of ongoing management activities designed to improve riparian and buffer functions. Several papers challenge underlying assumptions, while others suggest approaches or tools to assess or improve current management. Some studies focused exclusively on riparian ecosystems while others emphasized the interactions among riparian zones, other buffers, wetland ecosystems, and land use within the watershed and surrounding landscape. This set of papers also reflects the emerging integration of diverse disciplines, including socioeconomic dimensions, in the broadening study of riparian ecology and management. The challenge for scientists, practitioners, and resource managers is to expand this integrative approach, and then apply findings to the continued refinement of effective agricultural and forestry practices and regulations to meet the range of objectives for the design, maintenance, and restoration of riparian areas and other buffers. The results reported in the 17 papers of this special issue provide part of the foundation for this emerging approach to watershed and landscape management.

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